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METHOD AND APPARATUS FOR MEASURING THE NOISE CONTAINED IN A PICTURE

BACKGROUND OF THE INVENTION

The present invention relates to the field of signal processing for television receivers, and in particular to a method and apparatus for measuring the noise contained in a picture image to be displayed.

Noise reduction algorithms are used to improve the quality of noisy pictures. However, such algorithms reduce the picture quality when the noise level is small. It is therefore desirable to adapt the noise reduction algorithm to the degree of noise contained in the particular picture (i.e., in pictures that are not very noisy, only slight corrections should be made, while in pictures with poor quality, stronger corrections should be made). As a result, the noise contained in the picture must be quantified in order to assess the amount of noise reduction to be applied to the picture.

A standard measure for determining picture quality is often referred to as peak signal-to-noise ratio value (PSNR value). However, this measure requires a reference picture that does not include noise.

In the field of television, a known noise reduction technique includes measuring noise in the blanking interval of the respective TV signal (i.e., in those time intervals in which no active picture content is transmitted). Since the blanking interval of the TV signal is increasingly used for digital services (e.g., to transmit video text information) this technique is no longer available.

This problem becomes even more severe since the digital services that use the blanking interval of the TV signal differ from country-to-country.

Therefore, there is a need for an apparatus and method for measuring the noise contained in a picture that does not depend on the blanking interval.

SUMMARY OF THE INVENTION

To be able to measure the picture quality directly in the picture content, the noise must be separated from the picture content, so that the information about the noise contained in the picture is not garbled by the structures contained in the picture. The noise contained in the picture can be quantified, for example, in the form of a noise figure.

The invention achieves this by first finding homogeneous picture areas which have little structure. These homogeneous areas can be, for example, a nearly monotone picture background (e.g., a blue sky). Subsequently, the high-frequency signal component in these homogeneous picture areas is measured. The measurements are preferably averaged over several measurement points or over several successive pictures (e.g., in the TV application), so as to finally obtain quantitative information about the noise.

The operations for determining the homogeneous picture area as well as for measuring the high-frequency signal components are performed especially in terms of lines (i.e., the required accesses to the measurement data can occur line-by-line, corresponding to the scanned and digitized TV signal). The steps for determining the homogeneous picture areas as well as for measuring the high-frequency signal component are matched to one another, which facilitates implementing the present invention in hardware.

The homogeneous picture area is preferably determined by evaluating the luminance values of the individual pixels of the particular picture under consideration. For this purpose the picture can be divided into several adjoining blocks, which have several horizontally adjoining pixels. In one embodiment, the present invention evaluates picture areas that have five blocks, each with five horizontally adjoining pixels.

For each block, the DC component can be determined by a (1,1,1,1,1)-filter. If the difference between the maximum DC component and the minimum DC component of the five horizontal adjoining picture blocks lies within a given tolerance limit, this picture area, with a total of 25 pixels, can be regarded as homogeneous.

If a picture area has been recognized as homogeneous in this fashion, the high-frequency signal component can be calculated for each block of this picture area, for example by using a (1,-2,2,-2,1)-filter. The high-frequency signal components of the individual blocks of the homogeneous picture area are added up, so that finally the sum of these high-frequency signal components provide quantitative information about the noise contained in the particular picture under consideration, in the form of a noise figure.

In the embodiment that operates on the five blocks, each with five adjoining pixels, the calculation of the DC components and of the high-frequency signal components requires five clock cycles. Consequently, the data flow can be designed without wait cycles. Of course, the present invention is not limited to the procedure that processes picture areas with five blocks, each with five horizontally adjoining pixels. The width of the blocks (i.e., the number of pixels contained in each block) should not be too small, so as to make possible a reasonable statement about the existing DC component and the high-frequency signal component. On the other hand, the blocks should not be too large, since otherwise only very large homogeneous picture areas can be used in

the particular picture for measuring the noise. The subdivision of the picture into blocks of five horizontally adjoining pixels has turned out to be advantageous inasmuch as, in this case, an easily implemented high-pass filter (with only bit-shift operations) can be used to measure the high-frequency signal components, thus yielding good properties in frequency response.

In an alternative embodiment, the differences of the luminance values of two successive picture lines can also be used as input data for the inventive processing technique, rather than the luminance values of the individual pixels. An advantage of this technique is that the picture content is suppressed, since the formation of differences suppresses/filters-out vertical structures so that they cannot influence the noise figure. In addition, when using this technique, more homogeneous picture areas can be found, thus increasing the reliability of the information obtained about the noise contained in the picture, since the average covers a larger number of measurement data.

The output variable of the present invention in principle can be a single number that represents the noise (averaged over an adjustable region). However, information can also be made available about the position of the homogeneous picture areas contained in the picture. This information can be used for subsequent noise reduction, since the noise in non-homogeneous picture areas with an intensive structure is better concealed, and noise reduction at these points may lead to a garbling of the picture content.

These and other objects, features and advantages of the present invention will become more apparent in light of the following detailed description of preferred embodiments thereof, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a flowchart illustration of a technique for measuring the noise contained in a picture in accordance with a preferred embodiment of the present invention;

FIG. 2 is a pictorial illustration of the method shown in FIG. 1;

FIG. 3 is a block diagram of a circuit for measuring the noise contained within a picture.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is a flowchart illustration of a technique for measuring the noise contained in a picture in accordance with a preferred embodiment of the present invention. The method includes a step sequence 100-104, which is preferably traversed several times in succession, until a number of measurement points defined by an appropriate parameter have been processed. The steps 100-102 determine homogeneous picture areas. In particular, the picture luminance values assigned to each individual pixel are evaluated block-by-block, such that in one embodiment five adjoining picture blocks, each with five pixels, are always considered. The picture data are processed line-by-line. In step 100 an appropriate low-pass coefficient value LP is determined for each block. Then, in step 101, the difference value DIFF indicative of the maximum DC component and the minimum DC component of the blocks contained in the picture area under consideration is determined. Step 102 determines whether the difference value DIFF is within a prescribed and preferably adjustable tolerance limit value GAP. If it is not, the picture area is regarded as inhomogeneous and is discarded for calculating the noise figure. On the other hand, if the calculated difference value DIFF is less than the prescribed tolerance value GAP, the picture area under consideration is regarded as homogeneous.

In step 103, the high-frequency signal component in the corresponding picture signal is calculated for this homogeneous picture area. A high-pass coefficient value HP is calculated by a

filter for each block of the picture area under consideration, and the individual high-pass coefficients are summed up. The resulting sum value NOISE_SUM is indicated as the noise in step 104, and provides quantitative information about the noise contained in the particular picture under consideration. The method is repeated for the next homogeneous picture area of the same picture or for a successive picture, until a desired number of measurement points has been reached.

The method described above will be explained in more detail with reference to FIG. 2. The embodiment described below is especially advantageous for implementing the noise measuring technique in the hardware, since no wait cycles occur in the data flow.

FIG. 2 illustrates several horizontally adjoining pixels with the brightness or luminance value associated with each pixel. As already mentioned above, the picture data are processed line-by-line (i.e., the pixels shown in FIG. 2 are situated in the same picture line of the picture under consideration).

The picture is subdivided into several blocks BL, with every block BL having a certain number of horizontally adjoining pixels. In the example illustrated in FIG. 2, each block BL includes five pixels. For each of these blocks, the DC component (i.e., the average of the luminance values of the pixels contained therein) is calculated by a (1,1,1,1,1)-filter. That is, for each block BL a low-pass coefficient LP is calculated by the following relation:

$$LP(x',y) = \sum_{i=0}^{4} lum(i+5x',y) \qquad \text{(EQ. 1)}$$

LP(x',y) designates the low-pass coefficient of the block with block coordinates (x',y), while lum(x,y) designates the luminance value of the pixel with the pixel coordinates (x,y). The block with the block coordinates (0,y) contains the pixels with pixel coordinates (0,y), (1,y), (2,y),

(3,y), and (4,y). The block with the block coordinates (1,y) contains the pixels with the pixel coordinates (5,y), (6,y), (7,y), (8,y), and (9,y), etc.

By evaluating the low-pass coefficients calculated in this manner, homogeneous picture areas can be detected. In this process, picture areas BR are investigated that contain five adjoining picture blocks BL (compare FIG. 2), so that five successive low-pass coefficients LP are evaluated.

In the picture region BR under consideration, the maximum low-pass coefficient MAX(LP) (i.e., the maximum DC component of the blocks BL contained in this picture region BR) and the minimum low-pass coefficient MIN(LP) (i.e., the minimum DC component of the picture blocks BL contained in the picture region BR under consideration) are determined and the difference value DIFF = MAX(LP) - MIN(LP) are calculated. If the difference value DIFF is less than a given tolerance limit GAP, this picture region BR including 25 pixels is regarded as homogeneous and will be used for the measurement of the high-frequency signal component, which will be discussed in more detail later.

The tolerance limit value GAP is preferably adjustable. A stringent (i.e., narrower) tolerance limit makes the measurement more reliable, but on the other hand fewer homogeneous picture areas will be found, over which an average can be taken. Furthermore, a narrower tolerance limit makes the display of the measurement result slower for a given set of measurement points.

If a picture region BR has been recognized as homogeneous in step 102 (FIG. 1), the high-frequency signal component of the corresponding picture signal contained within this picture region is calculated in step 103 (FIG. 1). The high-frequency signal component of each block BL

of the homogeneous picture region BR is preferably calculated with a (1,-2,2,-2,1)-filter in the form of a corresponding high-pass coefficient HP as follows:

$$HP(x'y) = lum(5x',y) - 2lum(1 + 5x',y) + 2lum(2 + 5x',y) - 2lum(3 + 5x',y) + lum(4 + 5x',y) \qquad \text{(EQ. 2)}$$

HP(x',y) designates the high-frequency signal component or the high-pass coefficient of the block BL with the block coordinates (x'y), while lum(x,y) designates the luminance value of the pixel with pixel coordinates (x,y). The high-pass coefficients HP calculated for the individual blocks BL in this manner are summed in step 103 (FIG. 1) to form the noise value NOISE_SUM illustrated in FIG. 1.

Since both the calculation of the low-pass coefficients LP and the determination of the homogeneity criterion, as well as the calculation of the high-pass coefficients HP require five clock cycles in this embodiment, the data flow can be designed without wait cycles. The width of the blocks BL need not necessarily comprise five pixels. However, the width should not be chosen too small, in order to ensure reasonable information about the DC component and the high-frequency signal component is computed. On the other hand, the width of the blocks should not be chosen too large since only very large homogeneous picture regions in the picture can be used for measuring the noise. If blocks containing five horizontally adjoining pixels are used, the high-pass filter needed to calculate the high-frequency signal component can be implemented simply by bit-shift operations.

In the embodiment described above, it was assumed that picture regions BR contain five blocks BL, each with five horizontally adjoining pixels. However, homogeneous picture regions

with more than 25 pixels are also possible. For example, if the block with coordinates (x' + 5,y) meets the homogeneity criterion with the preceding four blocks, this block is also evaluated, so that a homogeneous picture region with more than 25 pixels results.

In the description of the above embodiment, it was assumed that the calculation of the low-pass coefficient LP and the calculation of the high-pass coefficient HP are performed by evaluating the luminance values associated with the individual pixels. In an alternative embodiment, the difference values of the luminance values of two successive picture lines can also be used. In this alternative technique for measuring noise, the picture content is suppressed by the formation of the difference, since the vertical structures are filtered out. Furthermore, with this procedure more homogeneous picture regions can be found, so that an average can be taken over a larger number of measurement data.

Even with non-noisy pictures the sum of the high-pass coefficients will not yield exactly the value zero. Consequently, prior to executing the technique illustrated in FIG. 1, the zero-point error should be found (i.e., the deviation of the sum from zero for a non-noisy picture). This zero-point error can then be compensated in measurements of noisy pictures by an appropriate offset value.

In the technique described above, the number of investigated picture regions can be adjusted after the measurement (i.e., the noise figure NOISE_SUM) is to be indicated. A quick indication has the result that pictures whose structure can falsify the measurement can be weighted more heavily. Also, by another parameter, the sensitivity of the measurement can be adjusted in the sense that, by an appropriate choice of this parameter, one can prescribe the noise intensity at which a full amplitude is to be indicated. Furthermore, by adjusting an appropriate parameter, the dependence between the number of measurement points found in a particular case and the size of

the tolerance range can be counteracted. If only a few measurement points per picture (i.e., a small number of homogeneous picture regions) are determined, the tolerance limit value GAP can be increased by a certain value, to permit the determination of the high-frequency signal component of such picture regions as would have been classified as non-homogeneous with the original tolerance limit value GAP. The tolerance limit value GAP can also be changed through several steps, such that the value by which the tolerance limit value GAP is changed depends on the particular number of homogeneous picture regions that are detected.

FIG. 3 is a block diagram illustration of a circuit for measuring the noise within a picture. In particular, a circuit for the embodiment working with line differences is shown. The luminance values of the individual pixels are input to a line memory 1 and stored. The luminance values are also input to a subtractor 2, which receives from the line memory 1 the luminance value of the corresponding pixel of the immediately adjoining picture line and calculates the difference luminance value. The difference luminance value from the subtractor 2 is input to the circuit sections 3-6 that calculate the DC components and the low-pass coefficients, as well as the circuit sections 7-13 that determine the high-frequency signal components (i.e., the high-pass coefficients). If the inventive technique described above is to be performed without forming the line differences, the circuit sections 1 and 2 can be omitted. In this case, the direct luminance values are input to the circuit sections 3-6 and 7-13.

The input values found in this manner are conducted to an adder 3 that include feedback through a register which is not shown. The adder 3 performs the summation to find the DC component. A counter 14 in combination with a multiplexer 4 assures that after every five clock cycles (in this embodiment), a new summation value is written as a new low-pass coefficient into a four-stage shift register 5. Through the four stages of the feedback shift register 5, the low-pass

coefficients LP of the last five blocks are conducted to an evaluation unit 6, which calculates the difference between the maximum low-pass coefficient and the minimum low-pass coefficient of the picture region under consideration, and compares this with the prescribed tolerance limit value GAP. If this difference is less than the tolerance limit value GAP, another multiplexer 11 is actuated. This multiplexer 11 is part of the circuit section for determining the high-pass coefficients.

The input values (i.e., the luminance values or the difference luminance values) are input to a bit-shift unit 7, which together with a series-connected adder 8, fed back through a register that is not shown, implements the previously described (1,-2,2,-2,1)-filter. Multiplexer 9 together with the counter 14 ensures that the output signal of the adder 8 is accepted after every five clock cycles and is conducted to a six-stage, fed-back shift register 10. Through the six stages of the shift register 10, the high-pass coefficients HP of the last seven blocks are always available. If the evaluation unit 6 recognizes that the picture region under consideration is homogeneous, the multiplexer 11 is actuated in such a way that the high-pass coefficients corresponding to this picture region, which up to now were stored in the shift register 10 or in the corresponding queue, are conducted to a series-connected adder 12, which is fed back through a register that is not shown, and are added to the current value of the noise figure NOISE_SUM. However, if no appropriate control signal of the output unit 6 is present, the multiplexer 11 outputs the value "0" and thus does not change the noise figure. After the process is completed, an indicator unit 13 outputs the noise figure NOISE_SUM, which is a quantitative measure of the noise contained in the picture under consideration.

According to FIG. 3, the shift register 5, in contrast to the shift register 10, is designed with only four stages, to make possible early detection of the homogeneous picture regions.

For the sake of simplicity, FIG. 3 does not illustrate any circuit sections that can be provided to normalize the noise figure NOISE_SUM (i.e., the noise figure is divided by the number of measurements) or to adjust the previously described parameters, although it is contemplated that such normalization and/or adjustments may be included with the noise detection technique of the present invention.

Although the present invention has been shown and described with respect to several preferred embodiments thereof, various changes, omissions and additions to the form and detail thereof, may be made therein, without departing from the spirit and scope of the invention.

What is claimed is: